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EXPERIMENTAL INVESTIGATION ON CONVECTIVE HEAT TRANSFER AND PRESSURE DROP IN VERTICAL AND HORIZONTAL HELICALLY COILED TUBE HEAT EXCHANGER USING MWCNT/ WATER NANOFLUID

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ABSTRACT

In this investigation, a compare the convective thermal energy transfer and pressure losses characteristics of Multiwall carbon nanotube water- based nanofluid in a shape of a helix coiled tube heat exchanger with the position is vertical and horizontal are presented. The experiments were conducted under turbulent flow and constant wall temperature regimes using MWCNT/water -based traditional fluid of 0.1percentage and 0.3percentage volume fractions. The examiner results indicate that there is no higher assorted between vertical and horizontal organize in the improvement of convective thermal energy transport and pressure drop of nanofluid evaluation to water. The Nusselt number is increased with increase the nanofluid volume fraction at turbulent flow.

KEYWORDS: Helically Coiled Tube, MWCNT/ Water, Nusselt Number, Nanofluid & Volume Fraction

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Original Article

INTRODUCTION

Improving in convective thermal energy transfer improves the execution of heat exchanger and also diminishes the regulation of the heat exchangers are the crucial issue in meeting out the cooling demand. In this method generally the heat transfer improvement techniques are two associative like Active and Passive techniques. The Active technique needs external forces and passive group needs special surface geometric face or fluids additives and various tube insert. Coiled tube configuration is generally performed in industrials like power plants, refrigeration and air-conditioning systems, pharmaceutical industries and food material industries. The coiled tube is of two types like helix coil and spiral coiled tube. Prabhanjan et al. [1] studied the thermal energy transfer coefficient in helix coiled tube higher than that of a similar geometry of straight tubes. Naphon et al. [2] recapitulated the thermal energy transfer and flow characteristics of single phase and two -phase flow through the bend pipe as both helical coil and spiral coil heat exchanger. Purandare et al. [3] presented the effect of shape of the bending coil and operating condition on the performance of helix coiled tube heat exchanger. Naphon et al. [4] investigated the heat transfer rate increase with increase the Dean number at different mass flow rate in spiral coil heat exchanger. Salimpour [5] presented the overall thermal energy transfer of shell and helix coiled tube working fluidd as a water. It is reported that the Nusselt number correlation and describe the thermal energy transfer rate in form of convection assorted while change the pitch of helixcoil tube. Choi [6] introduced a new traditional thermophyscial properties fluid with nano -sized dispersion nanopowder in the base fluids. Suggested that the heat

transfer performance of new nanofluids is better than that of water. Assael et al. [7] observed the thermal conductivity enhancement in nanofluids by using stabilized by SDBS (Sodium dodecylbenzene sulfonates). Ding et al. [8] studied the effective thermal conductivity increases with increasing temperature and volume concentration of MWCNT dispersed with Gum Arabic as a surfactant. Kumaresan et al. [9] investigated the new traditional heat transfer fluids as MWCNT/ water ethylene glycol blending mixture based nanofluids with SDBS as surfactant. The maximum improvement of thermal conductivity was 19.75% at 0.45 vol% MWCNT. Wen et al. [10] studied the convective heat transfer improved in the laminar flow condition with Al_2O_3 nanoparticle with water. It is suggested that the convective heat transfer enhances with Reynolds number as well as particle volume concentration. Suresh et al. [11] presented the convective heat transfer and friction factor characteristics of plain and helically dimpled under turbulent flow by Cuo water -based nanofluids. The heat transfer rate increase with increase Nusselt number at high volume concentration. Wang et al.[12] investigated the heat transfer and pressure drop of working fluids as water -based CNT nanofluids in circular tube as horizontal position. It is concluded that the enhancement of average convective heat transfer increase with increase the volume concentration of nanoparticles at constant Reynolds number. Kumar et al. [13] studied the heat transfer and pressure drop in helically coiled tube heat transfer working fluid as Al_2O_3 nanofluids under a turbulent flow region. The increases in inner thermal energy transfer and pressure losses are improved with increasing the nanoparticle volume fraction. Kahani et al. [14] investigated the effect of nanofluids concentration on heat transfer in a helically coiled tube heat exchanger under MWCNT/water nanofluid. The maximum achievable Nusselt number is obtained with small curvature ratio change and at increasing the pitch spacing of the helical coil tube. Palanisamy et al.[15] presented the heat transfer enhancement in direct cylinder glass solar collector using MWCNT nanofluid. The maximum possible solar collector efficiency 10- 29 percentage compare to water.

The researcher declaration, an indefinite of the examine investigation is carried out and describe the specific unique application of nanofluid as a working fluids in helix coil tube heat exchanger. In this connection, the main objective of this inquiring is to analyze the convective thermal energy transfer and pressure drop of shell and helix coil tube heat exchanger in vertical and horizontal position with MWCNT /water nanofluids as target fluid.

MATERIALS AND METHODS

The MWCNT nanoparticles were purchased from Nanostructured & Amorphous Materials, Inc. Houston, TEXAS, and USA. The purchased MWCNT nanoparticles were tested by XRD. The MWCNT nano -fine particle average size and shape are predicted to be between 50-80 nm, fine nanoparticle XRD pattern shown Figure 1. In this investigation the 0.3 vol. % MWCNT waterbased nanofluid is prepared by using two methods. Because two- step method is improved for nanostructure and this method gives higher stability and few agglomeration Ghadimi et al.[15]. The MWCNT water based nanofluids are prepared at 0.3% volume concentration and characterized with TEM are shown Figure 2. The obligatory sum of MWCNT nanopowder was taken and suspensions in DI water. Ultrasonic vibration (Citizen,) produce Ultrasonic vibration110 Watts at 40 ± 5kHz was switch on one hour to get the proper mixing and stable suspension of MWCNT nanopowder. nanoparticles are stable and tiny agglomerated particles are spherical in shape. It is found that there was no significant settled of MWCNT nanopowder even after 1 month of the static condition of nanofluid are shown Figure 3. The Sodium dodecylbenzene sulfonates (SDBS) as a stabilizer was comprehended to keep the stable of nanoparticles in base fluid.

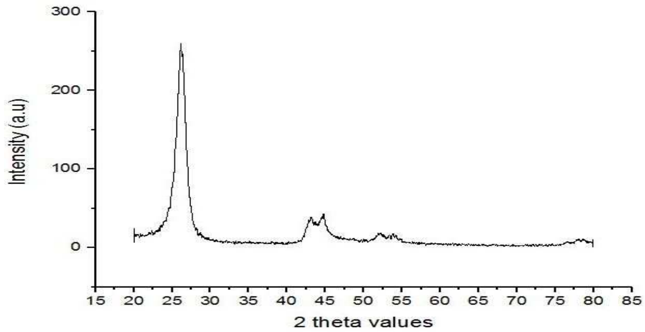

Figure 1: X-Ray Diffractometer Image MWCNT Nanoparticles

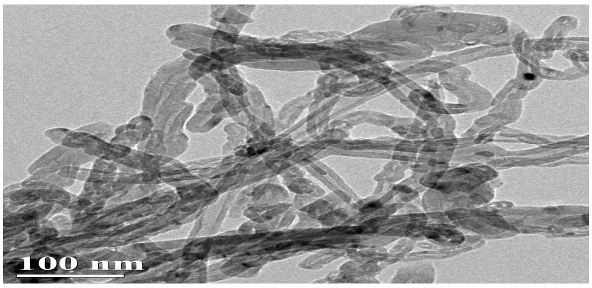

Figure 2: TEM Image MWCNT 0. 3 Vol. % Nanofluid

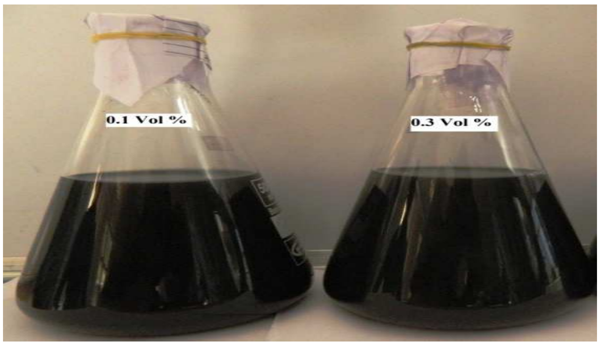

Figure 3: Photograph of MWCNT/ Water at Static Condition: 30 Days after Preparation

ESTIMATION OF THERMAL AND TRANSPORT PROPERTIES OF NANOFLUIDS

Pak and Cho [16], H. E. Patel *et al.,* [17] and Ebrahimnia-Bajestan *et al.* [18]. suggest the Equations. 1- 4 for calculate the thermal and flow characters such as Thermal conductivity, density, specific heat, and viscosity.

Density in kg/m^3

$$\rho_{nf} = \phi\rho_s + (1-\phi)\rho_w. \tag{1}$$

Heat transport capacity j/kg k

$$(\rho c_p)_{nf} = (1-\phi)(\rho c_p) + \phi(\rho c_p)_s \tag{2}$$

Thermal conductivity w/mk

$$k_{nf} = k_f \left[1 + \frac{k_p \varphi r_f}{k_f (1-\varphi) r_p} \right] \quad (3)$$

Dynamic viscosity, kg/m^{2}s

$$\left[\mu nf = \mu f (1 + 22.7814\varphi - 9748.4\varphi^2 + 1000000\varphi^3 \right] \quad (4)$$

DATA DEDUCTION FOR CONE HELICALLY COILED TUBE

The average thermal energy transfer and pressure drop in helical coil inner tube side Nusselt number is calculated from Eqs. (5) and (10).

$$Q_w = \dot{m}_w \, c_{p,w} (T_{in} - T_{out})_w \quad (5)$$

$$Q_{nf} = \dot{m}_{nf} \, c_{p,nf} (T_{in} - T_{out})_{nf} \quad (6)$$

$$Q = U_o \, A_o \, (\Delta T) \quad (7)$$

$$Q = h_i A_i (T_{wall} - T_{bulk}) \quad (8)$$

$$Nu_i = \frac{h_i \, d_i}{k_{eff}} \quad (9)$$

$$\Delta P = (\Delta \rho) \, gh \quad (10)$$

EXPERIMENTAL SET UP AND PROCEDURE

Figure 4: Test Section Helically Coiled Tube

The configuration speciation in this work handle helical coiled configuration (HCC). The test section helically coiled configurations are shown in Figure 4

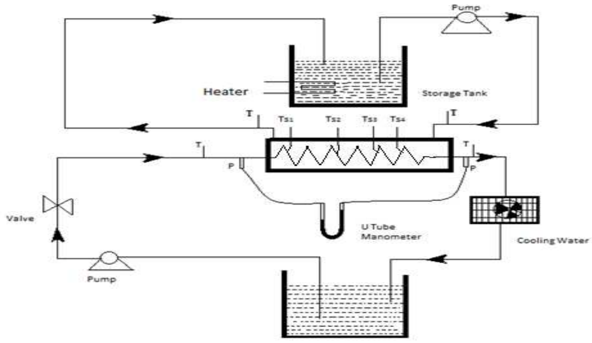

Figure 5: Schematic Diagram of Experimental Setup (Helically Coiled Test Section) Horizontal Position

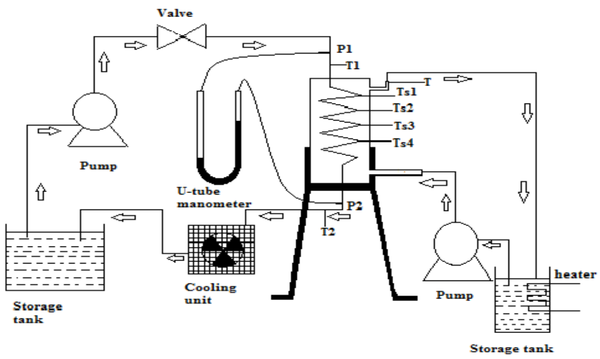

Figure 6: Schematic Diagram of Experimental Setup (Helically Coiled Test Section) Vertical Position

Figure 5 and Figure 6 illustrates the schematic experimental setup in horizontal and vertical position. The set-up has shell path flow and helically coil tube path loop. Shell side path handles hot water. The helically coiled tube path handles MWCNT / water based nanofluid. The shell path and coiled tube path flow are in opposite flow configuration. Shell side consisted of hot water container with a heating element of 1.5 kW ability, transport centrifugal pump and temperature controller. Tube side consisted of a centrifugal pump, ball gate valve to regulate the mass flow on helically coiled tube paths. Helix tube is made up of copper and shell is made up of mild steel. Four K-type thermocouples were located at same interval on the surface of the helically coiled tube to measure the surface wall temperatures. Flexible hose tube was used for all connections. U-tube Hg based manometer is connected other the helix coiled tube to measuring the head difference.

The hot water temperature is shell passage and storage container is maintaining temperature controller. In bothside heated water and cooling water are allowed to shell passage and helically coiled tube passage with aid of corresponding pumps. The corresponding observations were recorded when steady state condition. The U tube manometers indicate the value is noted. The helix coiled tube passage mass flow rate is varied and shell flow rate is maintained constant. The flow rates are predicted with collect nanofluid in the collecting point for an interval time with the high accuarcy measurement container and stopwatch. The same method is adopted for 0.1vol% nanofluid. Similarly, the test was conducted for water, 0.1vol% and 0.3vol% using the shell and helically coil tube heat exchanger. The mass flow of hot water is maintained a constant (0.15 kg/sec) in all cases inside coil tube mass flow rate is changed from 0.03 -0.07 kg/s.

DIMENSIONS OF TEST SECTION

The shell and Helically coiled tube test section have internal coiled tube diameter – 8, coiled tube external diameter -10,the External diameter of the Shell - 115, Effective length of the coil(L) -281, Coil pitch - 20, Diameter coil (D) - 98. Anumber of coil turns (n) – 16. All dimensions are in mm.

RESULT AND DISCUSSIONS

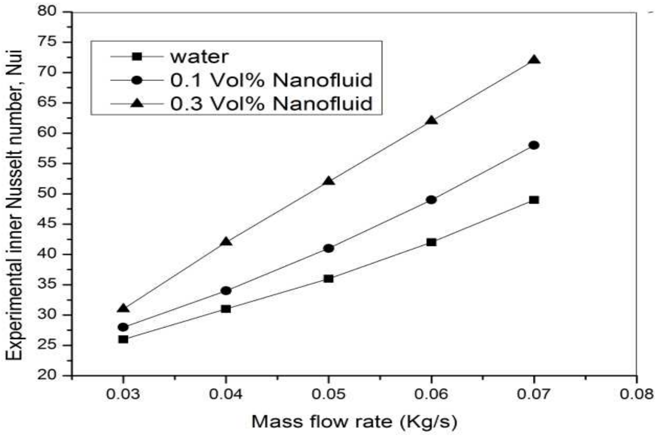

Figure 7: Experimental Nusselt Number with Coil Tube Side Mass Flow Rate

The experimental thermal parameter (Nu) with comprised to multiwall carbon nanotube volume fraction and mass flow rate range of 0.03–0.07 Kg/s in the horizontal position of helical coil heat exchanger are shown in Figure 7. Thermal parameter (Nu) growth with improves the mass flow rate and nanoparticle volume fraction. In a particular mass flow rate 0.07Kg/s, the rise in the thermal parameter for the Multiwall carbon nanotube as a target fluid 0.3% vol. fraction is 41% higher than that of water.

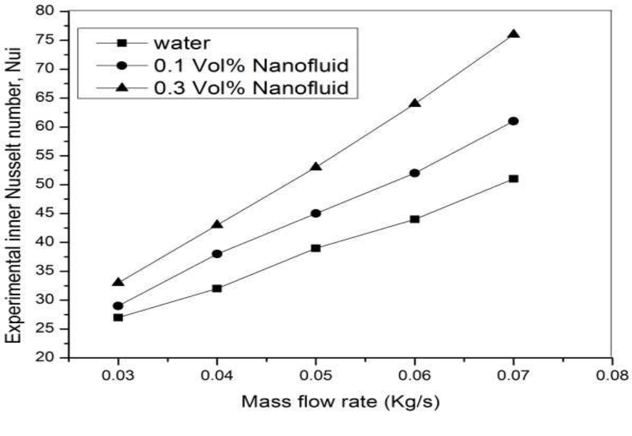

Figure 8: Experimental Nusselt Number with Tube Side Mass Flow Rate

Figure 8 indicates the Nusselt number with compared to the mass flow rate for water and Multiwall carbon nanotube waterbased nanofluids flow through the helical coil heat exchanger in a vertical position. The improvements of coiled tube experimental thermal parameter (Nu) are predicted to 43% at 0.3% vol. fraction and MWCNT/water nanofluids when compare to DI water. It results that there is a fine nanoparticle on encourage proper mixture and develop the strong secondary flow inside the helical coil. In this connection, improvement is due to excellent mixing of fluid, highly improved fluid parameter as a thermal conductivity and transport movement of MWCNT nanoparticles.

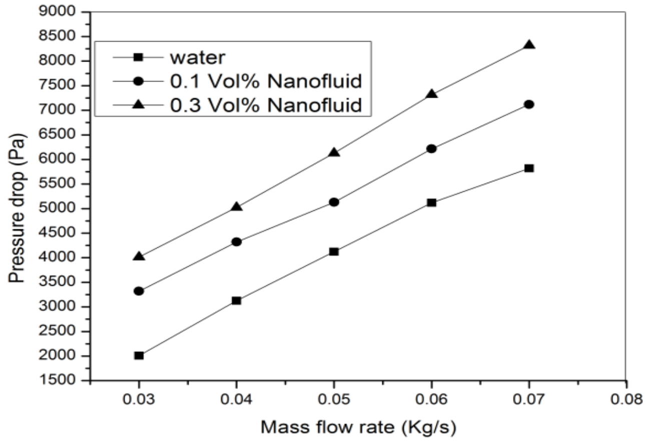

Figure 9: Variation of Pressure Drop with Tube Side Mass Flow Rate

Figure 9 presents the pressure drop of water, 0.1% and 0.3% vol. The fraction of nanofluids flows through helically coiled tube heat exchanger for the mass flow rate range of 0.03–0.07 Kg/s in horizontal position. The values of pressure drop grow with rise in mass flow rate and develop with the rise volume fraction of MWCNT nano particles. The more pressure drop different to water is minimum and develop in pressure drop is because of the rising in transport properties such as the viscosity of the MWCNT/water nanofluids. The average grows in pressure drop of 0.3% vol. fraction MWCNT/water target fluid(nanofluid) compare to water is 36%.

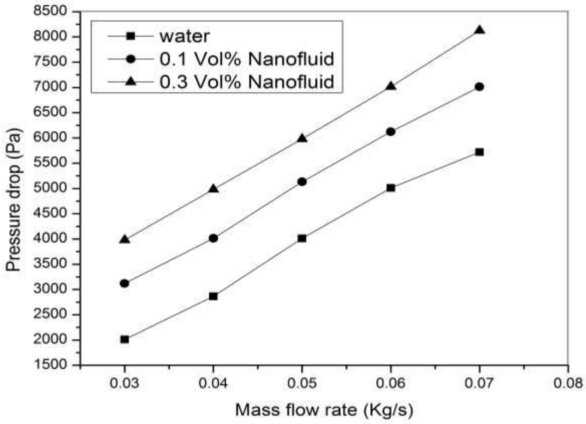

Figure 10: Variation of Pressure Drop with Tube Side Mass Flow Rate

The pressure drop of coiled tube heat exchanger is vertical position is shown in Figure 10. In pressure drop grow with the rise in mass flow rate and rising in pressure drop is notice for rise MWCNT / water fluid quantity fraction. The mean growth pressure drop for MWCNT water target fluid (nanofluid) compare to water is 33%.

CONCLUSIONS

The shell and helical coil tube heat exchanger are investigation to convective thermal energy transfer and pressure losses with a position of horizontal and vertical with MWCNT waterbased working fluid under turbulence flow. The 0.1% and 0.3% volume fraction nanofluid were predicted thermal parameter (Nu) 22% and 41% respectively when compare to water flow in a position of horizontal. The thermal parameter (Nu) are to predict 37% and 43% to 0.1% and 0.3% MWCNT/water nanofluid were found to be respectively when compared with water flow in vertical position. Based on the result to indicate clearly that, the thermal energy transfer improvement is higher in the vertical position than in horizontal

position. This is because of developments of strong intensity secondary flow improve the thermal energy transfer due to high in thermophysical properties of MWCNT/water as working fluid when compare with DI-water. The pressure losses were predicted 22% and 36% to 0.1% and 0.3% MWCNT/water working fluid respectively, Horizontal position compared the water. A pressure loss of 0.1% and 0.3% of nanofluids underflow is predicted 19% and 33% respectively in a vertical position. In this connection examine that the pressure losses of working fluids rise while increasing nanoparticle volume fraction in turbulence flow agreement.

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